

**UNITED STATES PATENT APPLICATION**

**FOR**

**X-RAY DETECTOR SYSTEM**

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## S P E C I F I C A T I O N

## TITLE OF INVENTION

## X-RAY DETECTOR SYSTEM

## FIELD OF THE INVENTION

**[0001]** The present invention relates to the general field of radiant energy imaging systems, and specifically to systems and techniques for detecting concealed items on or in objects.

## BACKGROUND OF THE INVENTION

**[0002]** Security systems are limited in their ability to detect contraband, weapons, explosives, and other dangerous objects concealed under a person's clothing or in an object, such as a box or bag. Metal detectors and chemical sniffers are commonly used for the detection of large metal objects and some kinds of explosives, however, a wide range of dangerous objects exist that cannot be detected with these devices. Plastic and ceramic weapons developed by modern technology increase the types of non-metallic objects that security personnel are required to detect. The alternative of manual searching of subjects is slow, inconvenient, and would not be well tolerated by the general public, especially as a standard procedure in, for example, airports.

**[0003]** Radiation exposure is an important consideration in x-ray concealed object detection systems. The United States National Council on Radiation Protection (NCRP),

in NCRP Report No. 91, "Recommendations on Limits for Exposure to Ionizing Radiation", 1987, addresses this issue. In this report, the NCRP states that a radiation exposure of less than 1000 microRem per year in excess of environmental levels is negligible, and efforts are not warranted at reducing the level further. Persons employed in high security or secured facilities, or those who frequently travel by airlines, may be subjected to many hundred security examinations per year. A yearly radiation exposure limit of 1000 microRem safely permits a single scan exposure within the range of 1 to 10 microRem for the general public. In accordance with the NCRP recommendations, radiation levels significantly higher than this may present some health risk.

**[0004]** Known prior art x-ray systems have limitations in their design and method which prohibit them from achieving the low dose and high image quality that are prerequisites to commercial acceptance. For example, radiant energy imaging systems that detect concealed objects carried on or in an object often scan pencil beam of x-rays through the object where the beam is transmitted or absorbed depending upon the concealed object, if any. A detector may be scanned vertically behind the object in step with the pencil beam to collect the transmitted x-rays.

**[0005]** U.S. Patent No. 5,181,234 (the '234 patent), herein incorporated by reference as if set forth fully herein, discloses an imaging system which does not require x-rays to be scanned through the object. The '234 patent discloses an imaging apparatus where a narrow pencil beam of x-ray radiation is scanned over the object whereby x-rays that strike low atomic number materials, such as soft tissue, are scattered (i.e. reflected) back

toward the apparatus. In comparison, x-rays that strike metal are mostly absorbed and generate very little scatter. Moreover, x-rays that do not strike the object are not captured or scattered back toward the apparatus since the x-rays continue until absorbed or scattered by items further behind the object. Detectors within the apparatus capture the scattered x-rays and generate a corresponding image. For example, as shown in FIG. 1, the vast majority of the body 12 appears light, as a result of the soft tissue generating significant back scatter of x-rays. Metals such as coins in the pocket 102 and belt buckle 103 appear dark due to their absorption of the x-rays. The background 104 around the body is also dark since there is nothing to scatter the x-rays back to the detector.

**[0006]** As shown in FIG. 2, a potential disadvantage of this approach is the difficulty in detecting metal objects that appear in front of or against the background 104 and not in front of the body 12. FIG. 2 shows a metal handgun 106 concealed under the subject's 12 arm. The handgun 106 is virtually impossible to detect in this view since both the handgun 106 and the background 104 appear dark. People may also hang or wear contraband on their sleeves or pant legs, which would be difficult to detect since it would be against the background and appear dark.

**[0007]** Another potential disadvantage of the prior art is that it provides no mechanism to control the x-rays not scattered or absorbed by the object. Currently, the x-rays not scattered or absorbed by the object continue until absorbed or scattered by other items beyond the object. Thus, no objects or persons should be within six to fifteen feet

of the apparatus otherwise the person or object will be unnecessarily exposed to the x-rays and may even appear in the image.

[0008] Thus, there is a need for an apparatus that would overcome the disadvantages of prior art x-ray systems and allow for the detection of concealed objects in the same plane as the background. There is also a need for a way to control x-rays that are not scattered or absorbed by the object to protect other persons from unnecessary exposure to the x-rays and to prevent image degradation.

## BRIEF DESCRIPTION OF THE INVENTION

**[0009]** The present invention provides for a method and apparatus to detect concealed items on or in an object by producing a pencil beam of x-rays from an x-ray source directed toward said object, scanning the beam of x-rays over the object, and detecting x-rays scattered from the beam of x-rays as a result of interacting with the object and a low Z material panel, the object located between the detector and the panel. The apparatus provides for an x-ray source to produce a pencil beam of x-rays directed toward an object, a scanner to scan the beam of x-rays over the object, and a detector to detect x-rays scattered from the beam of x-rays as a result of interacting with the object and the low Z material panel, the object located between the detector and the panel.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[00010]** The accompanying drawings, which are incorporated into and constitute a part of this specification, illustrate one or more embodiments of the present invention and, together with the detailed description, serve to explain the principles and implementations of the invention.

**[00011]** In the drawings:

FIG. 1 is a scan image created by an x-ray imaging system in accordance with the prior art.

FIG. 2 is a scan image illustrating potential disadvantages of imaging systems in accordance with the prior art.

FIG. 3 is a diagrammatic view of an imaging system in accordance with the prior art.

FIG. 4 is a diagrammatic view of an x-ray scanning system in accordance with the present invention.

FIG. 5 is a scan image created in accordance with one embodiment of the present invention.

FIG. 6 is a scan image created in accordance with another embodiment of the present invention.

FIG. 7 is a flow diagram illustrating a method in accordance with the present invention.

## DETAILED DESCRIPTION

**[00012]** Embodiments of the present invention are described herein in the context of a x-ray detector system. Those of ordinary skill in the art will realize that the following detailed description of the present invention is illustrative only and is not intended to be in any way limiting. Other embodiments of the present invention will readily suggest themselves to such skilled persons having the benefit of this disclosure. Reference will now be made in detail to implementations of the present invention as illustrated in the accompanying drawings. The same reference indicators will be used throughout the drawings and the following detailed description to refer to the same or like parts.

**[00013]** In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application- and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking of engineering for those of ordinary skill in the art having the benefit of this disclosure.

**[00014]** In accordance with the present invention, the components, process steps, and/or data structures may be implemented using various types of operating systems, computing platforms, computer programs, and/or general purpose machines. In addition,

those of ordinary skill in the art will recognize that devices of a less general purpose nature, such as hardwired devices, field programmable gate arrays (FPGAs), application specific integrated circuits (ASICs), or the like, may also be used without departing from the scope and spirit of the inventive concepts disclosed herein.

**[00015]** One embodiment of the present invention will be described with reference to the imaging system of the '234 patent. However, those of ordinary skill in the art will now realize that the present invention may be used with other imaging systems known in the art. FIG. 3 shows the imaging system 10 scanning a pencil beam 11 of x-rays over the surface of the body 12 of the person being examined. X-rays 16 scattered or reflected from the body 12 are detected by x-ray sensitive detectors 17. The detectors 17 are positioned for substantially uniform x-ray detection on all sides of the incident x-ray beam. The electronic signals 20 produced from the detectors 17 and synchronization signals 21 from the x-ray source 30 are routed into the digital computer 24. The computer 24 generates an image display 25 on a monitor (screen) 36 wherein the intensity at each point in the display corresponds to the relative intensity of the detected scattered x-rays.

**[00016]** As described in detail in the '234 patent, x-rays interact with matter in two ways: Compton scattering and the photoelectric effect. An x-ray interacting by Compton scattering is deflected out of the original x-ray beam creating back scattered radiation. The photoelectric effect, in comparison, absorbs x-rays and thus reduces the level of back scatter. At low atomic numbers and high energies, Compton scattering is more likely to

occur than the photoelectric effect. This gives rise to a large amount of scatter and the relatively high reflectance. At higher atomic numbers and lower x-ray energies, the photoelectric effect absorbs more of the x-rays resulting in less scatter and the low reflectance.

[00017] As shown in FIGs. 1 and 3, x-rays not scattered by the body 12 or object continue past the body 12 and are not scattered back to the detector 17 thereby creating a dark colored background 104. To overcome the disadvantages of having the dark background 104, a panel 400 is placed behind the object 12 as shown in FIG. 4. The panel 400 is preferably comprised of a low atomic number ("Z") material or materials with effective atomic numbers less than about 8, so that x-rays striking the panel 400 will be scattered back to the detector 17. Materials having a low effective atomic number relates to the average atomic number of a mixture of elements. For example, water has an effective atomic number of approximately 7.5 having hydrogen with an atomic number of 1 and oxygen with an atomic number of 8 (with oxygen being more important since it is heavier). Examples of low effective atomic number materials are epoxy, wood, masonite, water, and plastic materials such as polyethylene and acrylic. The panel 400 is preferably approximately one inch thick, but may be between one-half inch to two inches in thickness, and have a height of seven feet, but may have a height of between six to twelve feet. Those of ordinary skill in the art will now realize that other dimensions may be used depending upon the application. The panel 400 may be between two to six feet from the detector 17, but is preferably about three feet from the detector 17. For non-human scanning applications other distances may be used as appropriate. The panel 400,

located further from the detector 17 than the object 12, creates a continuous level of scattered x-rays having a generally different intensity than x-rays scattered from the object 12. Thus, when used with existing scanners in accordance with the printout, the panel produces a gray colored background in the image rather than a dark colored background 104 or a light color similar to the body 12.

**[00018]** FIG. 5 is an example showing the difference between having a panel and not having a panel behind an object. A one inch thick sheet of acrylic 500 was placed behind the body 12 on the lower left one-quarter 502 of the image. Moreover, the person 12 was instructed to hold two one inch diameter by twenty-four inch long metal pipes 504 and 506, one in each hand. As can be seen in FIG. 5, the left quarter image background 502, where the panel 500 is located, is brighter than the background 104 but darker than the body 12. Moreover, the metal pipe 504 on the left side is visible against the gray background whereas the pipe 506 on the right side is not visible against the black background 104. The panel 500 creates a gray background due to the x-rays that are scattered from the panel 500, the shade of gray being brighter than the black background 104 due to the scatter of x-rays but darker than the body 12 since the panel 500 is farther away from the detector than the body 12 thereby scattering x-rays with less intensity.

**[00019]** FIG. 6 is another illustration showing the difference between having a panel and not having a panel behind an object. However, FIG. 6 also shows an embodiment having the panel 600 located on the bottom of the object 12. In FIG. 6, a one inch thick sheet of acrylic was placed under the feet of the body 12 on the lower left one-half 602 of

the image. Moreover, two one inch diameter by twenty-four inch long metal pipes 604 and 606 were placed on the floor, one by each foot. As can be seen in FIG. 6, the left half of the image 602, where the panel 600 is located, is brighter than the background 104 but darker than the body 12. Thus, the metal pipe 604 on the left side is visible whereas the pipe 606 on the right side is not visible.

**[00020]** It will now be understood by those of ordinary skill in the art that the panel may be placed in different alternative positions. As shown in FIGs. 4 and 6, a floor panel 600 may be placed underneath the person 12 or object being scanned to detect, for example, objects in the shoes or on the legs or feet of the person being scanned. In another alternative embodiment, the panel may also extend outwardly from the sides and the top. Those of ordinary skill in the art will now realize that the panel may be formed of any shape such as a square, semi-circle, or any other shape around the person or object scanned.

**[00021]** As shown in FIG. 4, the present invention may also have a radiation shield 402 coupled to the panel 400 to capture any x-rays 11 that may pass through the panel 400, 600. This will ensure that any person behind the panel 400 will not be inadvertently exposed to x-rays. Moreover, the radiation shield 402 will ensure that objects behind the panel 400 will not be reproduced in the image 36. The radiation shield 402 may be made of any x-ray absorbing material such as steel or lead and be a few percent of the thickness of the panel 400.

**[00022]** The present invention also provides for a method for detecting concealed items on or in an object as shown in FIG. 7. An object or body is positioned in the x-ray scanning area 700 and a pencil beam of x-rays is scanned over the surface of the body or object 702 being examined. X-rays scattered or reflected from the body and a panel are detected 704 by x-ray sensitive detectors. The detectors are positioned for substantially uniform x-ray detection on all sides of the incident x-ray beam. The electronic signals produced from the detectors and synchronization signals from the x-ray source are inputted into the digital computer 706. The computer generates an image display on a monitor (screen) 708 wherein the intensity at each point in the display corresponds to the relative intensity of the detected scattered x-rays.

**[00023]** The panel is preferably made of a low Z material or materials with effective atomic numbers less than about 8, so that x-rays striking the panel will be scattered back to the detector. Materials having a low effective atomic number relates to the average atomic number of a mixture of elements. For example, water has an effective atomic number of approximately 7.5 having hydrogen with an atomic number of 1 and oxygen with an atomic number of 8 (with oxygen being more important since it is heavier). Thus, examples of low effective atomic number materials are epoxy, wood, masonite, water, and plastic materials such as polyethylene and acrylic. The panel is preferably one inch thick, but may be between one-half inch to two inches in thickness, and have a height of seven feet, but may have a height of between six to twelve feet. The panel may be between two to six feet from the detector, but is preferably three feet from the detector. Those of ordinary skill in the art will no realize that other dimensions may be

used depending upon the application. Moreover, for non-human scanning applications, other distances may be used as appropriate. The panel, located further from the detector than the object, creates a continuous level of scattered x-rays having a generally different intensity than x-rays scattered from the object. Thus, when used with existing scanners in accordance with the prior art, the panel produces a gray background in the image rather than a dark background or a light shade of gray similar to the body.

**[00024]** It will now be understood to those of ordinary skill in the art that the panel may be placed in different alternative positions. As shown in FIG. 6, a floor panel may be placed underneath the person or object being scanned to detect, for example, objects in the shoes or on the legs or feet of the person being scanned. In another alternative embodiment, the panel may also extend outwardly from the sides and the top such that the object or person being scanned is secured in an enclosure. Those of ordinary skill in the art will now realize that the panel may be formed of any shape such as a square, semi-circle, or any other shape around the person or object that is to be scanned.

**[00025]** A radiation shield may be coupled to the panel to capture any x-rays that may pass through the panel. This will ensure that any person behind the panel will not be inadvertently exposed to x-rays. Moreover, the radiation shield will ensure that objects behind the panel will not be reproduced in the image. The radiation shield may be made of any x-ray absorbing material such as steel or lead and be a few percent of the thickness of the panel.

**[00026]** While embodiments and applications of this invention have been shown and described, it would be apparent to those skilled in the art having the benefit of this disclosure that many more modifications than mentioned above are possible without departing from the inventive concepts herein. The invention, therefore, is not to be restricted except in the spirit of the appended claims.